

NATIONAL SECURITY SCIENCE



DETONATION

is in the details

Also in this issue

What's in the U.S. Nuclear Stockpile?

Secrecy and Surveillance: Threats to National Security?



Welcome to this issue of

NATIONAL SECURITY SCIENCE

This issue presents three very personal and timely perspectives on current national security topics.

The first perspective regards the events leading up to the birth of the Stockpile Stewardship Program and follows with a personal assessment of the program's current health. As seen by Joe Martz, a Los Alamos scientist who's seen it all—from the bottom up—assessing the health of the U.S. nuclear deterrent requires assessing the state of all its critical details.

Our second perspective comes from Martin White, who—before he unexpectedly passed away—was the United Kingdom's head of Strategic Technologies for its Ministry of Defense. The United Kingdom has ratified the Comprehensive Nuclear-Test-Ban Treaty and therefore is unable to test its aging nuclear stockpile to see how safe, secure, and effective its weapons are. The United States also no longer tests, so the two countries face similar challenges to maintaining their nuclear deterrents. Martin White wrote to explain to our NSS readers what the United Kingdom is doing to maintain its nuclear deterrent and how its approach is similar to, and different from, what the United States is doing.

Our third perspective is from Pulitzer Prize-winning journalist Judith Miller. She challenges us to reflect on the tension related to keeping our society free and democratic while also keeping it safe. What is our right to know—our need to know—and what protections should we afford members of the press, who keep us informed? As she writes, “[N]o democracy can survive for long without a free, independent, and occasionally irritating and even irresponsible press.”

I hope you'll read and ponder each of the personal, thought-provoking perspectives presented in this issue. I believe you'll find them eye-opening.

Craig Leasure

Principal Associate Director, Weapons Program (acting)

INSIDE THIS ISSUE



3

Detonation: From the Bottom Up

15 ► What's in the U.S. Nuclear Stockpile?

17

Modernizing for the Second Nuclear Age

23

Are Government Secrecy and Surveillance a Threat to National Security?

30

The Academies Come to Los Alamos for a Summer of Science

36

What Is an Air Force Fellow?

37

Then & Now

About the Cover

Nuclear weapons are mind-bogglingly complex. For them to perform as designed, thousands of specialized parts and subsystems must work together perfectly.

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An unarmed Minuteman III ICBM is launched out of a silo during a test at Vandenberg Air Force Base, California.
(Photo: U.S. Air Force)

DETONATION

FROM THE BOTTOM UP

Joseph Martz, a technical staff member at Los Alamos since the 1980s, has held a variety of positions during his 20 years in the Lab's Weapons Program. His responsibilities have included leadership of the pit technology group, management of enhanced surveillance in the Stockpile Stewardship Program, leadership of the weapon design division, and project head for the Reliable Replacement Warhead. NSS asked Martz for his thoughts on stockpile stewardship and its evolution over the last two decades.

Stockpile stewardship is a topic dear to my heart. I've been fascinated by it, and I've lived it—mostly on the technical side but also on the policy side. From 2009 to 2010 at Stanford University, I was a visiting scholar and the inaugural William J. Perry Fellow, working with Perry, former secretary of defense, and Sig Hecker, former Los Alamos Lab director (1986–1997). Together we looked at nuclear deterrence, nuclear policy, and stockpile stewardship and at where all this was headed.

The Nuclear World Changes

In my career, the years from 1989 to 1992 were the most consequential period with respect to nuclear weapons. Three very important things happened during those years, and they led to profound changes in U.S. nuclear policy. First, we had the fall of the Soviet Union, presaged by the fall of the Berlin Wall in 1989. The USSR dissolved on December 25, 1991, and the collapse of the USSR changed everything. The Cold War and its nuclear arms race were over, making an anachronism of MAD [Mutual Assured Destruction], the policy whereby, to deter nuclear war, the United States and the Soviet Union each deployed enough nuclear weapons to ensure the complete destruction of the other.

Second, in 1989 the government halted work at the Rocky Flats Plant, outside of Denver, Colorado, where plutonium pits for primaries [the nuclear triggers for thermonuclear weapons] were produced. That turned out to be a seminal moment in the history of the nuclear weapons complex because, frankly, it ended our ability to produce new weapons and effectively shut down the entire nuclear weapons production complex! Over the next 10 years, more than 50 percent of the historic nuclear weapons complex was shuttered forever.

Third, the Soviet Union had proposed a moratorium on nuclear testing and conducted its last test on October 24, 1990. "Divider," conducted on September 23, 1992, was the United States' last nuclear test. Shortly thereafter a moratorium on testing was legislatively mandated and has been followed by the United States.



The 1989 fall of the Berlin Wall was the beginning of the end of the Cold War.
(Photo: Open source)

Any one of those changes would have radically altered how the Lab carried out its national security mission, but all three events together put the Lab in unprecedented territory: instead of *designing and engineering* new weapons for the nuclear stockpile, it would now *maintain* the stockpile. But the cessation of nuclear testing meant the loss of the most important tool the weapons designers had used for 50 years to develop nuclear weapons and to ensure that the stockpile was safe, secure, and reliable.

Between 1989 and 1992, three events put Los Alamos in unprecedented territory.

In addition to closing the factories and putting a moratorium on testing, we'd also agreed not to develop new weapons. That meant we'd lose the means that, along with nuclear testing, had developed and maintained the skills of weapons designers: the continued design and production of new, upgraded nuclear weapons. However, maintaining the

designers' skills is vital because although the Cold War is over, shifts in global politics have engendered new national security needs such as protecting the weapons with enhanced security measures in the post-9/11 world. How were we going to manage an aging stockpile and remain agile in the face of changing national security needs?

Inventing "Science-Based" Stewardship

After the collapse of the Soviet Union, President Bill Clinton commissioned the first Nuclear Posture Review to examine the role of nuclear weapons in a post-Soviet world. This review (and every review since) reaffirmed the continued need for U.S. nuclear deterrence, while also recognizing the changing conditions and constraints in the global security environment. For itself and its allies, the United States would continue to maintain its nuclear stockpile, and nuclear deterrence would remain a central element of our supreme national security posture. But that presented the nuclear weapons laboratories with a huge technical challenge. How could the nuclear weapons labs ensure that nuclear weapons remained safe, secure, and reliable in the absence of nuclear testing?

The question was particularly important because the weapons were going to enter configurations that we had no experience with; that is, because we weren't continuing production, the weapons we had would, by default, age beyond their design life. Could we and our allies rely on these complicated weapons in spite of their aging? We would have to understand how age affected the weapons' performance, safety, and security and do that without any further nuclear testing.

This also meant finding new ways to train next-generation designers without the live tests the first generation had used.

How could we and our allies rely on these aging weapons in the absence of further nuclear testing?

Rethinking Mission "How To's"

Clearly, we had to rethink the entire problem of meeting our national security mission. Leading that process was Vic Reis, who at that time was assistant secretary for the Department of Energy (DOE) Defense Programs. He would be assisted by the directors of the three DOE weapons laboratories.

The lab directors, with Reis's guidance, convened technical experts from across the DOE weapons complex, and what the experts came up with was the realization that maintaining the stockpile would require an approach that was the complete inverse of the one used during testing. I'll explain what that means.

Continued on p. 6 ►

Nuclear Weapons 101

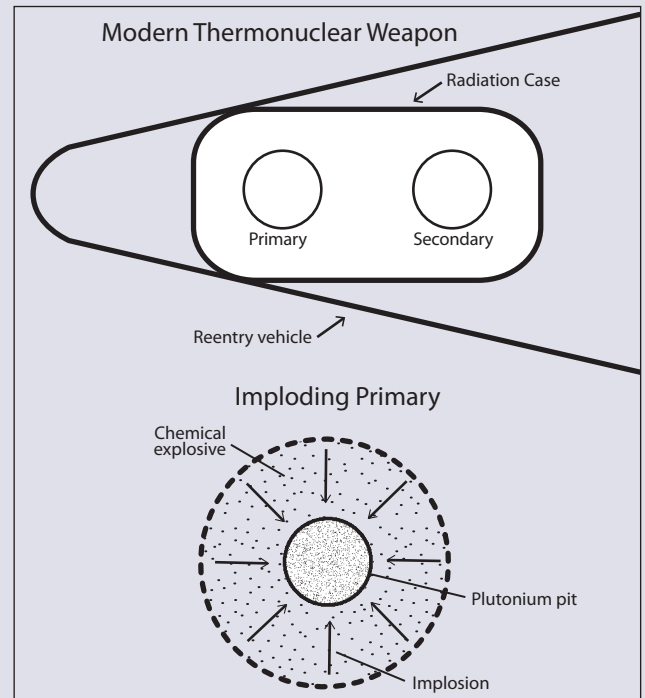
Nuclear weapons are complex devices operating at the extremes of physics, chemistry, and materials science. The temperature, pressure, velocity, density, and energy produced in a nuclear detonation are essentially unprecedented in human experience. Furthermore, the need to ensure the safety and security of nuclear devices leads to a great paradox: the weapon must be designed to ensure that its exceptional destructive power does not manifest itself when not desired but always does when required. And all the components that produce both results must be designed to fit within a volume and mass of material smaller than a kitchen stove.

A nuclear detonation can be viewed as a series of cascading, compounding events, each of which helps amplify energy production for use in the next main stage. A modern thermonuclear weapon has two main stages: the primary and the secondary. The primary is essentially a fission bomb that releases energy from a runaway fission chain reaction. That energy reaches the secondary, setting it off. The fuel in the secondary undergoes both fission and thermonuclear fusion and releases hundreds to thousands of times more energy than a fission bomb does.

Detonation of a modern thermonuclear weapon begins with an electrical signal to the primary, a signal that is scrupulously controlled to ensure it is transmitted only when there is certainty that a detonation is desired. This signal fires detonators in the primary that ignite a small charge of explosives, which in turn ignites the primary's main charge of explosives. The symmetrical detonation of this main charge is essential for compressing a pit of fissile material—material capable of undergoing nuclear fission—into a supercritical mass. Plutonium and uranium are the fissile materials most often used to make pits. When the pit is compressed into a supercritical mass, a runaway fission chain reaction takes off, generating tremendous amounts of energy very rapidly.

The energy from the primary is manifested as radiation, such as x-ray and neutron radiation. This radiation heats the weapon to temperatures exceeding the temperature of the sun. In modern, two-stage thermonuclear weapons, the primary's radiation is reflected from the radiation case onto the secondary, a component containing both fission and fusion fuels. The tremendous amount of radiation energy absorbed by the secondary creates a crushing shock wave that compresses the secondary into a state that produces vast amounts of fission, fusion, and radiation energy.

The yield from the secondary greatly exceeds what the primary can create. In an atmospheric detonation, the vast amount of radiation energy is absorbed by the air, creating a fireball that emanates thermal radiation and a tremendous shock wave, the sources of the direct damage from a nuclear explosion. Other effects of the nuclear detonation include direct radiation, both x-rays and neutrons, as well as nuclear fallout in the form of fission products.





The Rocky Flats Plant near Denver, Colorado, opened in 1952 to build plutonium pits for primaries, the triggers for thermonuclear weapons. Rocky Flats made thousands of pits per year in a plant with over 300,000 square feet of laboratory space. Pit production was temporarily halted in 1989 and completely discontinued in 1992. (Photo: Open Source)

◀ Continued from p. 4

From the Bottom Up

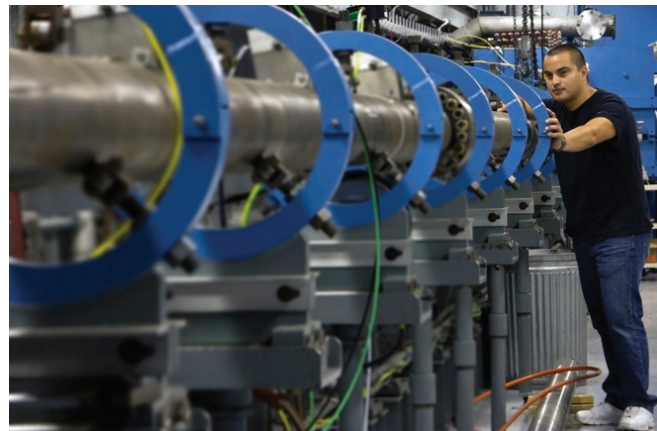
Nuclear testing was a wonderful tool. It was also the world's biggest shortcut. It meant that we didn't have to understand all the details of a nuclear weapon and how it functions. (See "Nuclear Weapons 101.") During the nuclear testing era, we knew enough about how things work and how materials behave to configure a device and make a prediction as to how it would perform. We then detonated it to see if it worked. It usually did, but sometimes it didn't, and we didn't always understand why. Basically, we solved the problem of building safety, security, and reliability into a weapon from the top down: if the full device worked, its components must be working. So we froze the design at this point and did our best to build systems that exactly replicated what we had tested.

Stockpile stewardship is all about doing nuclear testing on a computer. It's just damn hard on the computer!

In the post-testing era, we realized that without the top-down approach, we would have to piece together how nuclear weapons function from the bottom up—that is, gather all the basic science pieces underlying the behavior of each of the weapons' different materials and physical processes and then use that information to calculate how the complete nuclear weapon would function.

We quickly realized the best way to do this was to represent all this basic science as a series of mathematical models and then integrate all those models, along with copious amounts of data about physical properties, into a huge computer calculation that would accurately predict a weapon's performance.

To be sure the calculation was accurate, we would validate it by comparing its results with the data from past U.S. nuclear tests [over 1,000 of them] and the data from newly conducted "integrated" experiments. Integrated experiments reproduce in the real world some portion of how weapons perform, for



A gas gun at Los Alamos sends projectiles into targets at high speeds so scientists can study the properties of plutonium and other weapons materials at high shock pressures, temperatures, and strain rates. (Photo: Los Alamos)

example, how some configuration of materials in a warhead behaves when hit by shock waves during detonation. Thus, integrated tests would put real-world checks and balances on our virtual-world calculations of performance.

This was the bottom-up approach. It would enable weapons designers to make technically sound judgments about a weapon's performance without any new nuclear tests. In 1994, shortly after its conception, we named this approach "science-based stockpile stewardship," now the Stockpile Stewardship Program. A colleague of mine, Jas Mercer-Smith, has a good line about this. He likes to say, "Stockpile stewardship is all about doing nuclear testing in a computer. It's just damn hard on the computer!"

Finding the Fundamental Science Pieces

We realized in the early 1990s not only that computer calculations of weapon performance were going to take a level of computing power that didn't exist at the time but also that the basic science pieces for building those computer calculations were missing as well.

One of the missing science pieces was an understanding of many of the properties of weapon materials—for example, the strength and compressibility of many of the materials within the "physics package" (the energy-producing part of the weapon, containing explosives and fissile material)—and

how those properties changed under extreme pressures, temperatures, forces, and accelerations, especially after the materials aged.

In the nuclear testing era, we'd never thoroughly characterized the properties of the materials that went into the weapons—we hadn't needed to because the weapons were tested and regularly replaced. This limited characterization was no more evident than for the most important material in the weapon: plutonium.

For example, we didn't understand the details of how the plutonium sphere [the "pit" inside the primary of a nuclear weapon] gets compressed when its surface is hit by a strong shock wave from high explosives. The pressure from the shock wave causes the plutonium not only to implode [move inward] but also to get denser because the atoms in the plutonium are forced closer together [compressed]. But how much pressure causes how much compression, that is, how great an increase in density?

We needed to put that quantitative information into our computer codes so they could accurately predict exactly when, during implosion, the subcritical pit would reach a supercritical configuration needed to sustain a fission chain reaction. But we didn't have accurate experimental data to give us that quantitative information. Since we didn't know this, we certainly couldn't predict how decades of aging might change plutonium's ability to compress. In fact, we didn't even



The Los Alamos Plutonium Facility opened in 1978 to support nuclear weapons development and testing. After Rocky Flats was shut down in 1992, DOE tasked Los Alamos to begin pit manufacturing. The Los Alamos facility was the only one in the nuclear weapons complex that could be modified to do that kind of work. Compared with the 300,000 square feet at Rocky Flats, the Los Alamos Plutonium Facility has only about 60,000 square feet of laboratory space in which Laboratory personnel can conduct almost all the plutonium science and all the pit production in the United States. (Photo: Los Alamos)



For stockpile stewardship, Los Alamos scientists use 3D computer visualizations (like the one shown here) to understand the results of weapon performance simulations. (Photo: Los Alamos)

know whether its compressibility, strength, and metallurgical stability actually *would* be affected by aging. So one of the first things we had to do in stewardship was build the tools and facilities needed for measuring these types of material properties in plutonium and in other key weapon materials.

During the implosion of a primary, a precise sequence of processes must work together perfectly.

In 1997 I moved from the group that was charged with examining pits and plutonium, and I asked to start a program to study aging in *all* the materials within the weapon. We called this work “enhanced surveillance.” Initially, enhanced surveillance was a \$7 million program at Los Alamos, but within a few years, it grew to five times that size. By 1999 we had 40 science projects at Los Alamos, and another 100 projects at other labs and sites, devoted to learning how the various materials would age and how that aging would affect a weapon’s performance. Some of the country’s best chemists, engineers, and materials scientists became focused on aging nuclear weapons, and the success of their work formed a key basis for the Stockpile Stewardship Program.

Another missing science piece was a detailed quantitative understanding of the other physical processes that go on during a nuclear detonation. (See “Nuclear Weapons 101.”)

Through experience and nuclear testing, these processes had been partially measured and modeled, but never to the degree that would make us confident that a bottom-up calculation would be predictive, that is, would provide an accurate picture of exactly how all the processes fit together into a working whole.

To do the basic science experiments needed to improve our understanding of these processes and convert that understanding into mathematical models for high-resolution, 3D, bottom-up calculations of weapon performance, stewardship provided for a number of new research programs. It also provided for new facilities at Los Alamos, Lawrence Livermore, and Sandia National Laboratories. By the year 2000, DOE had established nearly a dozen “campaigns” to address these science issues. These campaigns have made tremendous progress in filling in the gaps in the myriad physics and materials issues of relevance to weapon assessment, and they continue to make advancements to this day.

Accelerated Strategic Computing Initiative

One important campaign was about investing in powerful new scientific computing capabilities—advanced, fast supercomputers and new computer codes—to perform the bottom-up calculations, which would include all the new fundamental science and data from new experiments. In other words, we would take all the new data on material properties, combine those data with the physics we learned, wrap all that into new weapons computer codes millions of lines long and developed over many years and have the codes step through a detonation piece by piece. The codes would mock up the nuclear weapon virtually, first in two dimensions and ultimately in three, using millions of pixels to model the exact shapes of weapon components. And the codes would track the changes in each pixel for many tiny increments of time to accurately simulate the detonation.

In the mid-1990s, a full-system bottom-up calculation—from the detonation of high explosives to the final energy release of the entire warhead—would have had to run for years to reach completion at our newly desired levels of detail. We needed to reduce that running time from years to months, and we needed to do it as soon as possible because most of the weapons designers with testing experience would be retiring over the next decade or two. Their real-life testing experiences would be critical to evaluating the accuracy of the computer models we hoped to generate.

At Nevada we built a state-of-the-art dynamic testing lab down in a mine.

We were running to beat the clock, so Reis, working at DOE, created ASCI, the Accelerated Strategic Computing Initiative. Under that initiative, DOE and the computer industry began producing, at an accelerated pace, computational platforms that started to break records in terms of their capabilities. For example, we reached 1,000 trillion calculations per second (petaflops) in 2008 with the Roadrunner supercomputer, a milestone that was widely considered impossible in the 1990s. Another important advance was the move to parallel processing. Thousands of processors were now used to compute different parts of the same problem simultaneously. These advances increased computational power from millions of calculations per second (megaflops) to trillions (teraflops) and eventually quadrillions (petaflops) of calculations per second. And all this was done to enable the massive calculations that were needed for modeling a nuclear weapon.

Integrated-Test Facilities

But it wasn't enough to have the fundamental data in the new codes and to run the new codes on the new supercomputers. We also needed to validate the predictions from the new codes as correct, so we brought to bear the third major investment

for stewardship, namely, facilities where weapons designers, old and new, could do integrated tests that reproduced some but not all aspects of weapon behavior. The real-world results from those integrated tests would provide a check on what the codes predicted for the same phenomena.

The most common integrated test today is, as it was in the testing era, the hydrodynamic test, or “hydrotest,” a non-nuclear test in which a replica of a primary undergoes implosion and the implosion is imaged by x-rays. These implosion experiments are called *hydrodynamic* tests because, at the high pressures attained during implosion, the materials flow like liquids. To keep the hydrotest nonnuclear, a surrogate metal is used in place of plutonium.

Hydrotests at DARHT

The most important integrated test facility at Los Alamos is DARHT [pronounced “dart”], the Dual-Axis Radiographic Hydrodynamic Test facility (see p. 41). At DARHT the hydrotest of a mock primary occurs inside a sealed steel test vessel, and two powerful x-ray machines set at a 90-degree angle to each other take simultaneous x-rays of the implosion process, giving us two views at one instant. One of the machines takes a single image, and the other captures a four-image sequence, thereby making a kind of a short “movie.”

Continued on p. 11

Down in a mine called U1a, at the Nevada National Security Site, two members of the Los Alamos staff prepare the front end of Cygnus, a powerful x-ray machine similar to DARHT. Two electron beams traverse the two parallel tubular sections (foreground and center) from right to left, are bent, and produce intense x-ray pulses behind the metal wall at the far left. The pulses emerge at a 60-degree angle to each other to record different views of an implosion experiment as in the Gemini experiments (p. 10). (Photo: Los Alamos)



Gemini Experiments

Revolutionary diagnostics at the U1a plutonium laboratory at the Nevada National Security Site (NNSS) have the potential to answer difficult questions about the aging of plutonium, pit manufacturing, features on a pit's surface, and certification of reused pits. In that way, it is possible that they will save billions of dollars in pit production costs.

Those diagnostics were in play during the recent Gemini experiments. Named after the constellation Gemini (the twin brothers Castor and Pollux in Greek mythology), the series consisted of twin hydrotests: scaled-down implosions that test material behavior in a condition similar to that of a weapon primary. The first test, Castor, was designed with a surrogate metal in place of plutonium. Pollux, which used plutonium, is referred to as a subcrit because it did not use enough plutonium to achieve a critical mass. The United States has used the NNSS to execute subcrits as part of stockpile stewardship since 1997.

The idea of the Gemini series was to compare the implosion behavior of a surrogate with that of plutonium. The use of surrogate materials is highly desirable—for example, they are less expensive to use, and production is easier. Surrogates are routinely used within the Weapons Program, but we are still studying the limits of their applicability as representatives of plutonium in hydrotests and other experiments. To what extent can experimenting with surrogates tell us how well aged plutonium pits or pits made with new manufacturing processes implode? Do the data obtained from experiments with surrogates contain gaps that affect the data's usefulness for validating the accuracy of the weapons codes? The Gemini experiments could help answer such questions.

The two shots were phenomenally successful. "Diagnostic equipment fielded by our scientists resulted in more data of this kind collected in this single experiment [Pollux] than in all other previous subcritical experiments," says NNSA Deputy Administrator for Defense Programs Don Cook.

"In both Castor and Pollux, the new photon Doppler velocimetry (PDV) diagnostic tool used hundreds of laser beams to continuously monitor the velocity of hundreds of points on the imploding material—all recorded while the material was being driven inward by shock waves from high explosives. PDV produces 10,000 times more data than previous techniques. It is like going from the dots and dashes of the Morse code to high-definition TV. Simultaneously, Cygnus, a powerful x-ray machine (see photo, p. 9), took x-ray snapshots of the implosion from different angles. Used together, x-rays and PDV have the potential to detect effects from aging, processing changes, and features that could impact weapon performance."

Cook continues, "This type of data is critical for ensuring that our computer simulations can accurately predict performance and thus is critical for continuing our confidence in the safety and effectiveness of the nation's stockpile."

In PDV the novel fiber-optic probe shown here measures the velocity distribution of the surface of an imploding pit (not shown) by using hundreds of very thin laser beams. When each laser beam reflects off that surface, its frequency shifts in proportion to the surface velocity at that point. Those shifts made by the different beams thus become a continuous time record of the velocity distribution.





The proton radiography facility at the Los Alamos Neutron Science Center, where a powerful proton beam can take “movie” images of a shock wave traveling through high explosives and other weapons materials. (Photo: Los Alamos)

◀ Continued from p. 9

DARHT’s images have unprecedented resolution, and we can compare them with our calculations to check whether the calculations simulated the implosion correctly. These capabilities make DARHT a unique experimental facility and critical to the stewardship program because having integrated experimental data for direct comparison with computer simulations is absolutely key to validating our codes and calculations. Lawrence Livermore also developed an important integrated-testing tool at the same time—the National Ignition Facility, NIF. While DARHT concentrates on hydrodynamics in the implosion stage of a primary, NIF is used for studies of later elements of weapon function that are also important to model and understand. DARHT and NIF are used by scientists from each laboratory to gain new understandings of weapons performance and behavior.

DARHT is a unique experimental facility and critical to the stewardship program.

Nevada National Security Site

Because we don’t use plutonium at DARHT, we needed to build a facility at the Nevada Test Site [now the Nevada National Security Site] where we could do integrated tests involving plutonium and high explosives. By both executive and congressional order, such experiments would have to be subcritical, “subcrits.” These are experiments that dynamically compress plutonium with explosives but must never produce a critical mass.

Over 20 years ago at the Nevada site, a shaft and its supporting network of tunnels were dug 963 feet below the desert surface. This complex, called U1a, was built to contain an underground nuclear test, but the test never took place. Over the last 15 years or so, U1a has been expanded and modernized into a highly sophisticated, unique laboratory with advanced diagnostics. Today, U1a is the only place in the nation where high-explosives-driven plutonium testing takes place. Cygnus (see photograph on p. 9), which is akin to a miniature version of DARHT, is an example of an advanced diagnostic at U1a. Cygnus takes x-ray pictures of plutonium as it is explosively imploded.

Recently, in collaboration with National Security Technologies, we added photon Doppler velocimetry, PDV, to our diagnostics. PDV uses hundreds of laser probe beams (see photo on opposite page) to provide substantially more and better data than previously possible, data that is used to better understand the dynamic behavior of nuclear materials.

In essence, we built a state-of-the-art plutonium-testing laboratory in a *mine*, a lab that is revolutionizing our ability to understand and assess how nuclear weapons function. The recent Gemini experiments (see opposite page), which won the prestigious Secretary of Energy Achievement Award, were conducted at U1a.

Proton Radiography

DARHT’s x-rays let us take a sequence of four images of the implosion of a surrogate weapon primary. Because it uses strong x-rays, DARHT is very good at imaging dense materials like metals. But many of a weapon’s materials (such

as explosives, foams, and cushions) aren't dense; they're relatively lightweight. When DARHT is tuned to look for the movement of metals, it can't easily image the movement of shocks in things like high explosives. This problem has been known for many years, and some very clever scientists at Los Alamos figured out that protons—the nuclei of hydrogen atoms—would make an excellent probe to image these lighter materials.

Hence, the science of proton radiography, pRad, was born. The pRad facility, an outgrowth of the Los Alamos Neutron Science Center (LANSCe), uses protons to take images of many of the materials in the physics package at high contrast. Proton radiography is especially well suited to studies of the movement of shock waves inside the explosives themselves. Very short pulses of protons, accelerated to over 80 percent of the speed of light, can penetrate these materials and create a sequence of 10 or more 2D “movie” images of, say, a detonation travelling through high explosives at 17,000 miles per hour.



Weapon Autopsies

An important element of stewardship is a surveillance program to monitor the aging of weapons in the stockpile. Each year the Navy and Air Force return several weapons of each type. Most of these are nondestructively examined and returned to the military. A small number of these weapons undergo destructive evaluation. In essence, we perform an autopsy on them. The weapon is disassembled into its components, and those components are sent back to their production agencies for evaluation. Pits are returned to Los Alamos, where we cut them open for detailed examination. Plutonium is extracted and subjected to a variety of tests to look for aging or for birth defects [flaws created during original manufacture]. These measurements are compared with the manufacturing records for that specific unit, and changes are noted that may have resulted from aging.

Cold War weapons were much like Ferraris: complex and lightweight, with high performance but little margin for error.

During these surveillance operations, if we find a deviation from specifications, we report this as a Significant Finding Notification, or SFN. The designers evaluate each SFN, and if they feel it requires further assessment, they elevate the notification to a Significant Finding Investigation, or SFI.

From 1995 to 2005, the three weapons laboratories opened and investigated a total of 156 SFIs. Of these 156 SFIs, 75 were determined to be “nonactionable.” In these 75 cases, the investigation and assessment revealed that no impact on safety, security, or performance was anticipated.

The remaining 81 SFIs were deemed to be actionable, and a component or material was changed, often as part of a scheduled refurbishment process, or a change was made to the certification of the weapon, usually as a limitation in storage, deployment, or military requirements. Using the tools of stewardship and the expert judgment of laboratory staff, these SFIs are being closed. In FY 2013 three SFIs were closed, and to date one SFI has been closed in FY 2014.

Pit Manufacturing

When the Department of Energy closed the Rocky Flats Plant, the facility had not completed enough W88 pits to support destructive surveillance activities. As a consequence, it became apparent that the nation needed to restore its ability to make more pits. That mission was assigned to Los Alamos by then secretary of energy Hazel O’Leary.

U.S. Air Force missileers prepare a Minuteman III intercontinental ballistic missile for a test launch at Vandenberg Air Force Base in California.

(Photo: U.S. Air Force)

This became the pit rebuild program, active from 1997 to 2010. In addition to resupplying pits for the Navy's W88 warheads, pit rebuild had three other important goals. One was to capture some of the manufacturing technologies previously used at Rocky Flats and put them to use at the Lab's Plutonium Facility. The second was to develop replacement technologies for those processes that couldn't be replicated. The third was to demonstrate that we could certify these newly rebuilt pits, along with certain new production methods, using integrated experiments, simulations, and other tools of stewardship.

Rebooting Aged Weapons

It is important to understand the design goals and characteristics of the Cold War-era stockpile, the stockpile we still have today. Weapons designed during the Cold War placed a premium on military characteristics designed to deter a specific adversary, the Soviet Union. One of the design goals was to stretch limited plutonium inventories as far as possible in order to build the most weapons from the limited supply of this strategic material. We were in an arms race with the Soviet Union, and every gram of plutonium mattered. If you could reduce the amount of plutonium in a weapon, you could build a few more weapons.

Optimizing yield to weight was everything. This didn't come for free.

At the same time, we wanted to optimize the yield-to-weight ratio in warheads going onto missiles: we wanted the biggest yield for the least amount of plutonium and in the smallest and lightest warhead package. This allowed the nation to place multiple warheads on a single missile, expanding the target set and enhancing Cold War deterrence. This was especially true for warheads on strategic missiles, where weight was at an absolute premium. Optimizing yield to weight was everything in our designs. This didn't come for free. The price we paid in optimizing lightweight designs for maximum yield was less margin for error and greater complexity—in some cases we made these warheads very complicated. The history of Cold War design at the national laboratories is one of exceptional success; we're very proud of the fact that we did, indeed, build very lightweight, compact, and powerful nuclear weapons. These weapons helped end the Cold War.

But we also didn't leave much margin in the performance of these designs. The margin for error was quite low. In these designs, even something small going wrong can affect the weapon's performance. We often compare weapon designs to sports cars. Cold War weapons were much like Ferraris:

complex, high performance, and lightweight, with little margin for error and with costly build and maintenance requirements. And it took not one nuclear test but in some cases up to a dozen to confirm that the highly optimized designs would work under all kinds of environmental and combat conditions. We tweaked these designs between tests to ensure they were operating as we intended, given their tiny margins for error.

Recall that during the Cold War we designed weapons to stay in the stockpile for 10 to maybe 20 years, certainly not 50 or 70 . . . or 100 years. New production and new designs had always replaced older weapons in the stockpile. But all this changed with the period from 1989 to 1992.

The result is that the age of our weapons today requires us to eventually refurbish and "life extend" each warhead. This refurbishment is the work of the life-extension programs (LEPs). The LEPs are designed to refurbish, modify, update, or replace components to ensure that the weapons remain safe, secure, and reliable for an additional 20 to 30 years. The LEPs were executed first for the W87 (a Livermore design) and then for the W76 (a Los Alamos design). The B61 bomb (also a Los Alamos design) LEP is now underway. Eventually, all the weapon types may be "rebooted" in this fashion.



Test launch of a Minuteman III intercontinental ballistic missile at Vandenberg Air Force Base in California. (Photo: Open Source)

The Silent Sentinels

Some people say nuclear weapons aren't that important anymore. In my mind nothing could be further from the truth. I recall a story from a few years ago. During a congressional hearing, a member of the military was asked, basically, what role nuclear weapons still had. Why did we still need them? The answer was, "Nuclear weapons function every day. They are our silent sentinels, reminding everyone of this country's ultimate means of reprisal . . . Those that would wish ill to the United States must always calculate, have second thoughts, when contemplating an act against us." That's deterrence.

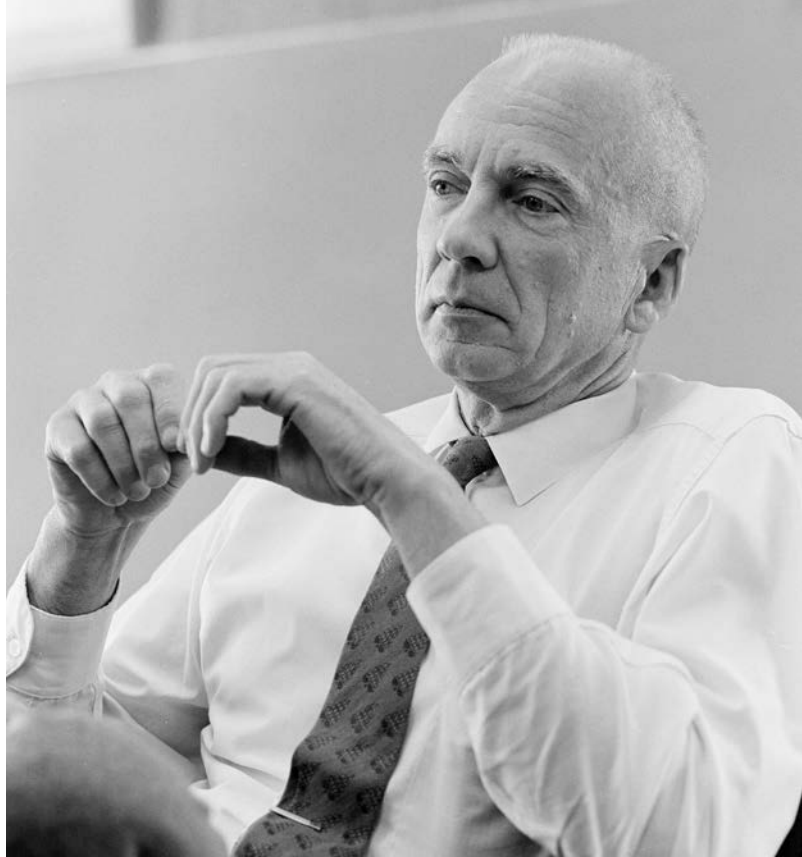
At a deep level, I don't like the fact that we have to threaten retaliation to maintain peace. However, that's the contradiction of deterrence. And from 1945 until today, it hasn't failed. It still operates. Norris Bradbury [the Laboratory's second director] used to call new staff members into his office for a short discussion. He would start by saying, "If the products of our work are ever again used in anger, then we will have failed in our mission. We don't build nuclear weapons to kill people. We build nuclear weapons to buy time for our political leaders to find a better way." Bradbury understood the contradiction of nuclear weapons—that we retain these objects of awful destruction in order to preserve the ultimate peace.

Nuclear weapons have a destructive power that current generations have never witnessed. They've never seen a nuclear weapon tested; it's only in the abstract that they can appreciate the awful power of these creations. Harold Agnew [the Laboratory's third director] proposed that once in every generation a nuclear weapon be detonated above ground, with world leaders required to witness it and see for themselves its sheer size and power. If each generation of leaders did this, they would surely never use a nuclear weapon.

A Better Way

Is there a better way? Can we achieve the benefit of deterrence while lessening the risks? These questions were a few that I examined during my time at Stanford University. I came to understand that the work of Los Alamos and the other weapons laboratories was growing in importance as the country and the world strove to reduce the sheer numbers of nuclear weapons. Indeed, could we find a roadmap to the vision Bradbury had of a better way?

I've come to believe that as stewardship has moved forward, there's been a new kind of payoff. As we become really good at understanding how nuclear weapons work and more confident that we can, with agility, reconstitute an arsenal to respond to new threats, that capability itself becomes a growing part of the deterrent. This is the future. Several prescient Lab staff members predicted this many years ago. Ted Gold and Rich Wagner, in consultation with John Immele, wrote a paper in 1990, "Long Shadows and Virtual Swords," which examined this strategy. The weapons that we designed at



Norris Bradbury, the Laboratory's second director (Photo: Los Alamos)

Los Alamos are not the sole protectors of our security. The work itself—the science and engineering—is also part of the deterrent. Elements of this strategy, a capability-based deterrent, have been adopted as part of the 2010 Nuclear Posture Review conducted by the Obama administration.

**We build nuclear weapons to buy
time for our political leaders to
find a better way.**

The most important element of stockpile stewardship and a capability-based deterrent is the *people*. I've been a witness to innovations that astound me to this day. The clever ideas, dedication, and work ethic of Los Alamos staff are extraordinary. There have been achievements here in support of stewardship that the previous generation couldn't have imagined. My greatest pride comes from interacting with hundreds of exceptional scientists and engineers at the Laboratory. The challenge in capability-based deterrence is ensuring an agile capability. We must be able to respond to world developments with sufficient agility so that no one doubts our ability to overwhelm and defeat an adversary.

In a very real sense, our deterrent will evolve so that it's not just the products of our work—the nuclear systems we design and maintain—but our work itself that will become the protector of our security. In this vision, the Laboratory is more important than it ever was, and that's where we're headed. ✦

~Joseph Martz

What's in the U.S. Nuclear Stockpile Today?

For decades the size of the United States nuclear weapons stockpile remained shrouded in mystery. It was only in 2010 that the Department of Defense declassified the number of stockpiled weapons from 1962 forward. Since reaching a peak of 31,255 weapons in 1967, the stockpile has gradually declined in number.

Today's stockpile is down to about 2,200 weapons, due in large part to the end of the Cold War and the arms-control treaties that followed. However, there was another very important historical factor driving the downsizing of the stockpile: advancements in nuclear weapons science and technology.

When the United States had a nuclear monopoly in the late 1940s, it felt secure enough that it built very few weapons. However, the Soviets tested their first nuclear weapon in 1949, and that, coupled with the need to offset the Soviet Union's huge advantage in conventional forces, drove the need to build up a large, credible nuclear deterrent. The nuclear arms race was on. The U.S. stockpile grew rapidly, and so did advancements in nuclear science and technology.

During the 1950s and '60s, U.S. warhead (and delivery system) technology significantly improved. New weapons, like advanced atomic bombs, thermonuclear weapons (aka hydrogen bombs), and new tactical nuclear weapons (like artillery shells with nuclear warheads) were added to the stockpile. Previous weapons designs, though rendered obsolete, could not be dismantled fast enough and remained in the stockpile.

The next era of nuclear weapons design, which began in the late 1960s, was characterized by fewer major breakthroughs in basic weapons science but more major refinements to existing weapon designs. A primary goal was to design ever-smaller weapons with the maximum explosive yield possible. These refinements also meant weapons systems were more robust, more versatile, and more accurate. In addition, for the first time, they included pioneering safety features to ensure the weapons could be detonated only when authorized by the president. Together, these refinements formed the technical foundation for the modern stockpile. For example, that era produced the B61 nuclear gravity bomb, which entered service in 1966. Today, the B61 is the oldest weapon design in the current stockpile and is now undergoing a life-extension project (LEP).

As this trend continued, fewer types of weapons were developed in the 1970s and '80s, but these weapons were even more sophisticated. As a result, only seven types of weapons make up today's stockpile. Thus, while advancing technology initially allowed the stockpile to grow to tens of thousands of weapons, technology has now allowed it to be sharply reduced yet still do its job—and do it even better.

Los Alamos National Laboratory's contribution to the current stockpile is monumental. Of the approximately 2,200 weapons in today's stockpile, Los Alamos designs account for approximately 90 percent. The Lab designed five of the seven weapon types in the stockpile. In addition to the Air Force's B61, Los Alamos designed the W78 warhead on the Air Force's Minuteman III intercontinental ballistic missiles and the W80 warhead on its cruise missiles. Los Alamos also designed the W76 and the W88 warheads on the Navy's submarine-launched ballistic missiles. Lawrence Livermore National Laboratory designed the W87 warhead, also on the Minuteman III, and the B83 nuclear gravity bomb. ✨

~Alan Carr



The Royal Navy's Vanguard-class nuclear submarine. The Vanguard-class submarines are nuclear powered and armed with Trident nuclear-armed ballistic missiles.
(Photo: United Kingdom Ministry of Defense)



MODERNIZING FOR THE SECOND NUCLEAR AGE

The late Martin White, the author of this article, was the head of Strategic Technologies for the Ministry of Defence (MOD) of the United Kingdom (U.K.). He was tasked with ensuring that the U.K.'s defense-related nuclear science and technology capability, primarily centered at the Atomic Weapons Establishment (AWE), is developed and maintained at a level consistent with meeting the MOD's nuclear deterrent policy requirements.

This article is a personal view, and hopefully it gives a flavor of current U.K. thinking. It reflects my thoughts on the future, what I believe is the continued importance of our nuclear deterrent, and by implication, the importance of the scientific collaborations that underpin it.

The U.S. and U.K. Partnership

In March 1940 a U.K. memorandum, “*On the Construction of a ‘Super-bomb’ Based on a Nuclear Chain Reaction in Uranium*,” resulted in the establishment that April of the Military Application of Uranium Detonation (MAUD) committee. MAUD was to evaluate the possibilities of a “super-bomb.” The following year [1941], MAUD announced it considered “the scheme for a uranium bomb . . . practicable and likely to lead to decisive results in war.”

The United Kingdom initially started out alone, under the code name Tube Alloys. However, the scale and cost of the effort led to the recommendation that the project should be pursued under an Anglo-American effort. In August 1943 Prime Minister Churchill and President Roosevelt signed the secret Quebec Agreement. In December the first contingent of British scientists arrived at Los Alamos.

It is from this point on, with a notable gap, that our two nations’ nuclear warhead programs have been closely linked. The gap, of course, was a result of the United States’ Atomic Energy Act of 1946 [aka McMahon Act], which among other things, prohibited the sharing of any U.S. nuclear weapons information [considered “restricted data”] with another country, even close allies. This meant that the United Kingdom went back to developing its own nuclear program during the time this piece of the McMahon Act was in place. [The act was modified through the signing of the 1958 U.S.–U.K. Mutual Defence Agreement to allow nuclear information sharing.]



Cloud from the United Kingdom's Operation Hurricane atomic bomb test, October 3, 1952. (Photo: Open Source)

The U.K. Nuclear Program

Since 1959 we have retained close collaboration. It is worthy of note that by 1952 the United Kingdom had exploded its first atomic device: Operation Hurricane, a plutonium fission bomb. Rapid development of more-powerful designs followed, including the test in 1957 of the first U.K. thermonuclear bomb design. The United Kingdom went on to develop a number of warheads fitted to a variety of air-delivered weapon systems, from Blue Danube [1953] and the WE177 free-fall bomb [1966] to nuclear depth charges.

The inevitable development of standoff weapons and terminal defenses meant that a step-change in the development of strategic systems was required from the 1960s forward. The procurement of the Polaris missile [a U.S.-designed and -built, nuclear-equipped, submarine-launched ballistic missile (SLBM)] represented that step-change for the United Kingdom in the maintenance of our nuclear deterrent and a further development in a much closer relationship with, and dependence on, the United States.

While the subsequent U.K. Chevaline program [meant to improve the Polaris weapon system] represented a return to a greater level of U.K. independence, the purchase of the Trident II D5 strategic weapon system [another U.S.-designed and -built, nuclear-equipped SLBM] marked a further development in our collaboration with the United States.

In 1994 the declared maximum number of warheads taken on a U.K. Trident patrol [U.K.'s Vanguard-class nuclear submarines, armed with U.S. Trident II D-5 SLBMs] was 96. After the 1997 "Strategic Defence Review" [published in 1998], reductions were made, resulting in 48 or fewer warheads per boat, and the total stockpile was reduced from 300 to fewer than 200. With fewer warheads came fewer missiles, and the U.K. purchase order went from 65 to 58.

So by the end of the 1990s, the United Kingdom was reliant on a single nuclear deterrence system—something that had not happened since the 1950s. And so it remains today.

By the end of the 1990s, the United Kingdom was reliant on a single nuclear deterrence system—it remains so today.

The United Kingdom operates a minimum credible deterrent. It fields a single Vanguard-class submarine [from a fleet of four] with up to 40 warheads, on patrol at all times, in a posture we call Continuous at Sea Deterrence (CASD). CASD also forms part of our commitment to NATO.

It is therefore of paramount importance that this single-system capability, reliability, and effectiveness is maintained and is not eroded by age, obsolescence, or emerging threats.

The U.K. Stockpile Stewardship Program

Since the cessation of nuclear testing and ratification of the Comprehensive Test Ban Treaty [CTBT] in 1998, U.K. confidence in the nuclear weapon stockpile has been maintained through the development and exploitation of a program of science-based stockpile stewardship activities. And that scientific understanding is firmly rooted in our collaborative efforts that can be traced back to the 1943 Quebec Agreement.

Demonstration of our deterrent capability now rests in part on our commitment to sustaining large-scale investments in the cutting-edge facilities and science that must now underpin, what I would call *assure*, the U.K. deterrent warhead.

Our confidence in our warhead capability and performance is underwritten through the credibility of our scientists and engineers and our Nuclear Weapon Stockpile Management Program, conducted mainly at the AWE. What is important is that much of this work is peer reviewed by American subject-matter experts, including our colleagues here at Los Alamos.



The 24-foot-long Blue Danube was the first nuclear weapon stockpiled by the United Kingdom, beginning in November 1953. Based on the Hurricane, it was of limited production and basically built in a laboratory setting. (Photo: Open Source)



The WE177 was the last U.K. air-delivered, free-fall nuclear weapon. It was deployed during the late 1970s and retired in March 1998, ending the U.K. aircraft-carried nuclear weapon capability. (Photo: Open Source)

As the stockpile ages, and materials and processes change, we must examine our weapons for signs of degradation, predict the effects of these changes, and be ready to refurbish or remanufacture our stockpile of weapons. We are ever more reliant on accelerated-aging trials data and predictive aging models to give us the extended warning window we need to respond with our manufacturing capacity. These are concerns both countries share.

Once built, refurbished, or remanufactured—or perhaps, depending on political decisions, eventually redesigned—U.K. warheads must be certified *in the absence of underground tests*. This certification process requires unique capabilities:

- Supercomputing, which allows numerical models to be developed and used to predict material behavior and performance in the environment of an operating nuclear weapon.
- Hydrodynamics, which generates the necessary data to test and develop these models, particularly for the nuclear primary.
- High-energy-density physics experiments, which yield data relevant to thermonuclear burn, radiation transport, and operation of the nuclear secondary.

The United Kingdom has had decades of experience in pursuing this predictive modeling approach. We conducted much fewer nuclear tests than other nuclear weapon states—some 40 compared with over 1,000 for the United States—partly because we had an intensive aboveground experimental program and a strong model-based strategy for certification of nuclear yield. The same model-based approach is being exploited to do the following:

- Predict warhead behavior throughout the stockpile-to-target sequence and provide assurance of warhead survival and successful operation.

A Polaris SLBM on display in the Imperial War Museum. The U.S.-designed Polaris missile was later improved through the U.K.'s Chevaline program. The improvements included a sophisticated decoy package to counter the Soviet Union's anti-ballistic missile defenses. (Photo: Open Source)





A Trident II missile being test fired from a Vanguard-class nuclear-powered submarine. The first batch of British Trident warheads was completed in September 1992. The warheads were designed by the AWE and are probably similar to the U.S. W76 warheads now on U.S. Trident missiles. Production of the British warhead ceased in 1999. (Photo: Open Source)

- Plan scenarios and consequences of execution.
- Predict warhead survivability.
- Manage boat manifests against the life of the out-loaded warheads.

Our assurance of the effectiveness of our nuclear deterrent is a direct result of these studies and of the resilience of our capabilities in terms of people, facilities, equipment, and programs.

Modernizing the U.K. Nuclear Weapons Program

You may know that we are in a period of *major* investment at AWE in terms of workforce, facilities, and programs. In the past decade, the workforce has grown from a low of 3,000 to the current 4,500. That represents a huge challenge and culture change for AWE: training the new workforce, at the same time as delivering the program and at the same time as the site recapitalization presses forward. The facilities-build program aims to replace much of the 1950s infrastructure at AWE, with 4 major projects and over 30 others underway.

By the end of this decade, we will have new uranium, high-explosives, and assembly facilities. Just as crucial, we will have a state-of-the-art high-power laser, supercomputing, and new hydrodynamic experimental capabilities. This last, the Teutates project, is a groundbreaking Anglo-French facility being constructed in Valduc, France. It will achieve initial operating capability in two years' time and when it is complete will be the most capable hydrodynamics facility in the world.

And this investment in the future is *not* just at AWE. We are developing our next generation of naval nuclear reactor plants. We are, together with the United States, building a common missile compartment for the next generation of ballistic submarines.

Since issue of the 2006 white paper, "*The Future of the U.K. Nuclear Deterrent*," the government has spelled out its continuing commitment to maintaining a ballistic, submarine-based nuclear deterrent capability. This was expressed most recently by our prime minister on the occasion of the completion of the 100th Vanguard patrol [on April 3, 2013], when he set out the arguments for renewing our Trident missile deterrent system.

Although we have been described as one of the most reluctant nuclear nations to own a deterrent, I would argue that the ab initio way in which deterrence policy is generated (as in the 2006 white paper), along with the transparency that attends the ensuing debate, means that the strategies formed as a result are stronger and all the more defensible for it.

U.K. Nuclear Stockpile Reduction

We can also point to a proactive stance when considering deterrent reductions. The 2006 white paper confirmed a further reduction of the operationally available warheads from a limit of 200 to a limit of 160. This represents a halving of the operational stockpile since 1997. As our then secretary of state Des Browne commented in 2007, this left us with the smallest stockpile of all the recognized nuclear states.

In the 2010 "Strategic Defence and Security Review," the stockpile was reduced by a further fifth, to no more than 120 operationally available warheads out of a stockpile of no more than 180.

So what does all this mean in terms of lessons for the future?

When Teutates is completed, it will be the most capable hydrodynamics facility in the world.

The Equation of Deterrent Costs

In terms of affordability and sustainability, the reductions have made little or no difference. There have been some



The late Martin White speaking at the 2nd Los Alamos Primer lecture series, held in celebration of the Laboratory's 70th Anniversary. (Photo: Los Alamos)

savings on missile procurement, but in terms of warheads, our major cost is opening the gates to a safe and secure AWE site. The only way you can influence the equation of deterrent costs is to do one of the following:

- Reduce the number of deterrent systems. But we have only the one: Trident missiles.
- Move to a cheaper, but still effective and credible, deterrent

system. Successive and exhaustive studies over the last few years have consistently shown that the terms “cheaper” and “effective and credible” are mutually exclusive where U.K. nuclear deterrence requirements are concerned. The government has just completed the Trident Alternatives study. The study makes no recommendations because it was a neutral, fact-based analysis and not designed to change government policy—which is to maintain a continuous deterrent and to proceed with the government’s program to build a new fleet of ballistic missile submarines.

- Build a system that lasts forever with little or no maintenance. This is not feasible, and anyway, what happens to your nuclear expertise in the meantime? We’re still busy recapturing and exercising capabilities lost in the last 20 years since the building of the Trident system.
- Get even greater efficiency through collaboration between nuclear weapon states. We have the 1958 U.S.–U.K. Mutual Defence Agreement and the Polaris Sales Agreement with the United States. And we have a 2010 treaty with France through which we are delivering the Teutates project. But there is *definitely* room for growth in collaborations. However, these take time.

Future Arms Reductions

We expect negotiated arms reductions to follow a predictable path: a continuous, smooth mathematical function, if you will. There is, so far, no strategic shock envisaged. That implies that the process will be pursued with a focus on our need to maintain a capability to meet policy needs. So the question of conflict between deterrence requirements, deterrence assurance, and deterrence reductions does not occur, at least for the foreseeable future.

We also need to recognize that we cannot simply turn our nuclear capability off and on. History has taught us that reinstating a lost or reduced capability is a very expensive exercise.

Finally, we must guard against strategic imbalance and the impracticality of arms reductions verification: an equation that gains relevance as numbers reduce. In anticipation of the United Kingdom’s eventually being included in multilateral arms limitation discussions, the United Kingdom has a healthy program of research into arms verification technologies. These methodologies are exercised in lifelike conditions with the United States and, for added realism, a third party: Norway.

This strategy follows a well-worn path. In the past, we found great advantage in understanding the full implications of the CTBT for our nuclear weapons program by scoping and researching the applicable technologies invoked by the treaty. To do otherwise would be to jeopardize the sustainability of our deterrent program and to risk the adoption of ineffective measures of treaty verification.

Continued close work with Los Alamos lies at the heart of the U.K. program’s sustainability.

In all this, our interactions with the United States have been and remain pivotal in shaping the U.K. deterrent program. And our continuing collaborations with Los Alamos National Laboratory touch the very core of our technical capability.

This is best evidenced by our recent collaboration on trials at U1a [a test facility at the Nevada National Security Site], where independent U.K. predictions of performance were compared with the experimental data. This represented a significant peer review, given that more data were gathered in those two trials than were collected during the entire pre-CTBT nuclear test program. The good news is that predictions and data matched quite well. And the United Kingdom continues to field experiments on the Los Alamos Dual-Axis Radiographic Hydrodynamic Test facility and has secondees within the Los Alamos weapons design teams.

In the area of national nuclear security, our teams continue to challenge and peer review each other, with exercises conducted by U.K., French, and U.S. experts. It is clear to me that our collaboration and, within it, our continued close work with Los Alamos lie at the heart of the U.K. program’s sustainability. ✦

~Martin White



Are Government Secrecy and Surveillance a Threat to National Security?

Judith Miller covered U.S. national security issues for 28 years at The New York Times. There she was part of a small team that earned a 2002 Pulitzer Prize for reporting on global terrorism. She has continued covering national security issues since becoming a national security commentator for Fox News in 2008. She is also an adjunct fellow at the Manhattan Institute in New York, where her writings focus on the Middle East, counterterrorism, and the need to strike a delicate balance between national security and American civil liberties in a post-9/11 world. Here is her personal view on U.S. secrecy, surveillance, and national security.

Almost eight years have passed since December 2006, when I spoke at Los Alamos and discussed the Bush administration's priority—following the attacks of September 11, 2001—on countering the proliferation of nuclear weapons. While the president was determined to oust the Taliban from Afghanistan and destroy Osama bin Laden's Al Qaeda, he was also determined to stop “rogue” states and terrorists from acquiring a nuclear weapon and other weapons of mass destruction (WMD), even if it meant resorting to preventive actions like the war in Iraq.

I explored how and why Libya under Col. Muammar Qaddafi had decided to come in from the “nuclear cold” and also abandon his chemical weapons program in the wake of America's invasion of Iraq. Libya's renunciation of WMD, alas, was the sole “success” story in nonproliferation that the administration could claim after discovering that Iraq didn't have unconventional weapons—which I had sadly discovered as the only reporter embedded with the Army unit that had the seemingly endless, miserable task of hunting for and securing Saddam's nonexistent arsenal.

Although it turned out that Saddam didn't have unconventional weapons, Charles Duelfer told us in his meticulous report and subsequent book [*Hide and Seek: The Search for Truth in Iraq* (2009)] that Saddam had preserved the infrastructure and expertise to restore his WMD programs quickly. He fully intended to do that once economic sanctions against his country were lifted. In my speech seven years ago, I argued that unlike Libya, North Korea and perhaps Iran had drawn the opposite lesson from America's foray in Iraq, namely, that possessing a nuclear weapon was the best way of preventing an American or other foreign invasion on their soil. As a result, Pyongyang and Tehran (the latter after an initial suspension of its nuclear program) intensified their quests for entry into the nuclear club following America's Iraqi invasion.



Judith Miller speaking at the 2nd Los Alamos Primer lecture series, held in celebration of the Laboratory's 70th Anniversary. (Photo: Los Alamos)

We were almost all wrong about Saddam's WMD. But some of us may have been right about North Korea, Iran, and other players seeking nuclear weapons under cover of the Nuclear Nonproliferation Treaty.

Possessing a nuclear weapon was the best way of preventing an American or other foreign invasion on their soil.

In his book *The Second Nuclear Age*, author Paul Bracken discusses his disheartening thesis: we have entered a "second nuclear age," which is characterized by a greater number of nuclear-armed players. All these new players, he argues (and I agree, sadly), mean greater political instability and potential for strategic miscalculation and a nuclear exchange—even greater than in the bad, or good, ol' days of the Cold War. When President Bush left office in 2008, there were eight members of the "nuclear club." Now, in President Barack Obama's second term in office, we may well see an expansion of that club, especially if Iran cannot be persuaded to abandon its program. Iran's neighbors are unlikely to permit the non-Arab Persian Shiite state to be the only Muslim country in the Arab Middle East with nuclear weapons.

Given this worrisome tableau, some experts see President Obama's search for dramatic reductions in the U.S.-Russian arsenals as disconnected from the strategic reality that Bracken describes. In fact, Obama's apparent desire to reduce the American strategic arsenal down to 1,000 nuclear warheads

may send a signal the president does not intend: he may be playing a nuclear numbers game at the expense of geopolitical stability.

South Korea and Japan are openly debating acquiring nuclear weapons.

According to Will Tobey and Bill Schneider, stability may actually be undermined by dramatic reductions in America's strategic arsenal. Tobey, for one, has argued that the likelihood of war will not be affected by reducing nuclear arsenals down to 1,000 warheads. And Schneider warns that the administration's utopian aspirations for "nuclear zero" are proceeding in a manner that appears oblivious to what is happening outside of the U.S.-Russia arms control effort. [Tobey is a former deputy administrator for defense and nuclear nonproliferation at the Department of Energy's National Nuclear Security Administration and is now a senior fellow at Harvard's Belfer Center. Schneider now chairs the Pentagon's Defense Science Board.]

There is some evidence, alas, to support such concerns. South Korea and Japan, for instance, are now openly debating acquiring nuclear weapons as their confidence in extended deterrence is strained by America's obsession with heading for zero nuclear weapons. While going to zero may be a worthy goal in and of itself—and I think that 1,000 nuclear weapons are more than enough to protect the homeland—the Obama administration's stated policy may have the unintended consequence of undermining the core goals of the Nuclear Nonproliferation Treaty. It may even help trigger the treaty's demise if countries seek to replicate the deterrence once provided by the United States with their own nuclear weapons.

As a journalist who writes often about national security, I'm struck by how little I've written about nuclear arms negotiations, or arms control in general for that matter, since September 11, 2001. Yes, the attacks highlighted the potential danger to America if Al Qaeda and other like-minded fanatical groups were to obtain WMD. But the attacks also demonstrated the nation's intense vulnerability to suicide bombers and other unconventional attackers armed with the most conventional of weapons—in one example, simple box cutters. As we all know, September 11 sparked the now notorious "global war on terror," which had as much to do with eliminating anti-U.S. militants as with denying them access to the unconventional weapons they were seeking, and continue to seek.

But the point I want to make is that after 9/11, combatting terrorism took center stage in American national security. Terrorism became the first of the "new national security threats," a strategic challenge that nuclear weapons once occupied. Entire sets of "new rules" of the

national intelligence game were written. The intelligence community—indeed, the government itself—reorganized.

Terrorism resembles the threat of nuclear weapons: the overall numbers may be greatly reduced, but the danger cannot be totally eliminated.

Consider the Department of Homeland Security, created to oversee the war on terror at home and having some 250,000 employees, half of whom are contractors. That agency, while always somewhat dysfunctional, has remained long after Osama bin Laden and over two-thirds of Al Qaeda's top leadership have left the scene. While the militant Islamic threat itself has metastasized, spreading nodes and like-minded "wannabe's" in nations throughout the world, the threat once posed by "Al Qaeda Central," or "Al Qaeda Core," as terrorism experts call it, has significantly diminished. But the nation's bureaucracy has not yet adjusted to this new terrorism reality. Billions are still being spent, much of it wasted, on fighting an enemy whose capacities have, for the moment, been severely reduced.

President Obama said as much in his speech of May 2013 at the National Defense University. Because Al Qaeda has been on the "path to defeat" in Afghanistan and Pakistan, he said,

the United States had to focus instead on spin-off and peripheral threats: Al Qaeda in the Arabian Peninsula and other networks of foreign and homegrown "violent extremists" that threaten America. All wars end, President Obama said. But the conundrum for any politician is that militant Islamists may not see it that way or may have a different sense of time.

The problem with such a unilateral declaration is that it risks sounding hollow and premature should the *jihadis*, known for their legendary patience, one day acquire the means to inflict major damage, yet again, on an American city or other target. In this respect, terrorism resembles the threat posed by nuclear weapons: the overall numbers may be greatly reduced, but the danger cannot be totally eliminated.

Perhaps that is why the president spoke, yet again, about closing Guantanamo, ending such abuses of human rights as torture (the Bush administration had already promised to end torture), and bringing drone strikes under the rule of law, which he has yet to do.

A second new national security threat against which America has made great strides since 9/11 is biological weaponry. At a cost of over \$7 billion a year since the anthrax attacks less than a month after 9/11, the nation has done much to combat this still much-underrated WMD. The anthrax letter attacks killed 5, infected 17, shut down post offices throughout the Eastern Seaboard, and caused billions of dollars in damage. Since then, strategic stockpiles of drugs and antibiotics have been created and placed at strategic locations throughout the country, air sniffers and sensors have been installed in major cities to more quickly detect the presence of abnormal pathogens in the air, and mail to sensitive locations is routinely scanned for dangerous substances. Hundreds of thousands of first responders and public health officials have been taught to recognize the signs of a biological attack.

The U.S. government has implemented, in whole or in part, most of the measures that Steve Engelberg [of *ProPublica*, formerly of *The New York Times*], Bill Broad [*The New York Times*], and I advocated in our 2001 book, *Germs, Biological Weapons and America's Secret War* (which, by the way, we started writing years before 9/11 and the anthrax attacks). And yet the potential—for good and for evil—inherent in the startling advances of the biotech revolution have still not been fully appreciated by defense planners, and not by most journalists either. Bioterrorism remains an underappreciated strategic threat to the nation, the "also ran" of WMD.

The third strategic "threat du jour" is clearly cyber. Long considered more of a nuisance than a strategic challenge, private and state-sponsored hackers and cyber warriors have now moved onto center stage in national defense. The recent description of the new Cyber Command and its capabilities that General Keith Alexander presented at a national security meeting in Aspen, Colorado, suggests how seriously the Obama administration now takes this threat. The fact that our nation's chief economic rival, China, and one of its most



UNITED STATES DISTRICT COURT
FOR THE DISTRICT OF COLUMBIA

KLAYMAN et al.,

Plaintiffs,

v.

OBAMA et al.,

Defendants.

KLAYMAN et al.,

Plaintiff,

v.

OBAMA et al.,

Defendants.

Civil Action No. 13-08

FILE

DEC 16 2013

Clerk, U.S. District & Bankr.
Courts for the District of Colo

to
December 16, 2013 [Dkt. # 13 (No. 13-0851), # 10 (No. 13-0881)]

MEMORANDUM OPINION

On June 6, 2013, plaintiffs brought the first of two related lawsuits challenging the constitutionality and statutory authorization of certain intelligence-gathering practices by the United States government relating to the wholesale collection of the phone record metadata of all U.S. citizens.¹ These related cases are two of several lawsuits² arising

¹ Plaintiffs' second suit was filed less than a week later on June 12, 2013, and challenged the constitutionality and statutory authorization of the government's collection of both phone and internet metadata records.

² The complaint in *ACLU v. Clapper*, Civ. No. 13-3994, which was filed in the United States District Court for the Southern District of New York on June 11, 2013, alleges claims similar to

UNITED STATES DISTRICT COURT
SOUTHERN DISTRICT OF NEW YORKAMERICAN CIVIL LIBERTIES
UNION, et al.,

Plaintiffs,

-against-

JAMES R. CLAPPER, et al.

Defendants.

WILLIAM H. PAULEY III, District Judge:

The September 11th terrorist attacks revealed, in the starkest terms, just how dangerous and interconnected the world is. While Americans depended on technology for the conveniences of modernity, al-Qaeda plotted in a seventh-century milieu to use that technology against us. It was a bold jujitsu. And it succeeded because conventional intelligence gathering could not detect diffuse filaments connecting al-Qaeda.

Prior to the September 11th attacks, the National Security Agency ("NSA") intercepted seven calls made by hijacker Khalid al-Mihdhar, who was living in San Diego, California, to an al-Qaeda safe house in Yemen. The NSA intercepted those calls using overseas signals intelligence capabilities that could not capture al-Mihdhar's telephone number identifier. Without that identifier, NSA analysts concluded mistakenly that al-Mihdhar was overseas and not in the United States. Telephony metadata would have furnished the missing information and might have permitted the NSA to notify the Federal Bureau of Investigation ("FBI") of the fact

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13 Civ. 3994 (WHP)

MEMORANDUM & ORDER

In December 2013 a federal judge in Washington, D.C., deemed the NSA's collection of U.S. telephone records to be likely unconstitutional. But less than two weeks later, a federal judge in New York ruled the collection lawful. This means the Supreme Court will ultimately have to rule on the issue. (Photo: Open source)

ardent ideological foes, Iran, both place enormous priority on this type of warfare highlights its enormous potential for mayhem. Indeed, even our nuclear infrastructure, including government labs such as Los Alamos, have been targeted. Yet the nation's most pronounced vulnerability remains its private sector, which has often resisted government help in shoring up its operating and communications systems against external attacks, which have already materialized.

The fifth challenge to national security is the administration's "war on leaks."

Fortunately, America also excels at this type of warfare, as seen most dramatically by use of the "Stuxnet" computer worm to slow Iran's centrifuges.

A fourth major national security challenge is climate change—the conservatively correct term for global warming. I won't discuss that today because I haven't covered it.

But I would like to spend the rest of my speech addressing a *fifth* challenge to national security: growing government secrecy and what First Amendment advocates (like me) call the administration's "war on leaks." This is a war not only on the government officials and contractors who leak—and I think many of them who are not whistleblowers are fair game—but also on the reporters who disseminate leaked information and, in the process, ensure that the nation has a free and independent press. The global war on terror may be over, but the Obama administration's war on leakers and the press is not. And this has implications for us as a nation and for the balance between protecting national security and preserving our personal privacy and civil liberties.

Here at Los Alamos, secrecy is paramount, and essential, for obvious reasons. But much of what is now classified in the nation should not be secret. Our government, in the name of national security, has been indulging in a classification orgy—especially since 9/11. But has such secrecy enhanced or impaired national security?

Consider the following: last year the U.S. government classified over 92 million documents as secret. According to the Reporters Committee for a Free Press, the government has been classifying documents as secret at a rate of over 125 a minute. When I first heard that statistic, I thought that was impossible. The government can't do anything that fast! But apparently, it can.

Moreover, according to the National Archives, the government has used some 60 new categories of secret information, many of them created since 9/11, to limit the disclosure and distribution of millions of documents that were once available to the public. Dana Priest [*Washington Post* journalist] and William Arkin [independent journalist] spent two years trying to find out how much was being classified by how many people. And in their articles and a recent book [*Top Secret America: The Rise of the New American Security State*, 2010], they found that nearly a million people—860,000, in fact—have a top-secret clearance, and 1,900 private companies work at the top-secret level. So do another 1,100 federal government organizations. If you were to put all of them on a map, Priest said, you would have over 17,000 locations because a lot of the companies and agencies with this level of secrecy operate out of multiple buildings.

The classification effort is not cheap. In 2004 alone, the government spent \$7.2 billion stamping 15.6 million documents “Top Secret,” “Secret,” or “Confidential.” The costs have risen almost every year. Only in the past two years has the rate of document classification begun to slow.

Do we have the right balance between secrecy and civil liberties?

In my own area, biological terrorism, things that used to be open are now closed, and much of what I thought the public had a right to know is now classified. I doubt very much, for instance, that our book on biological weapons could even have been written if we had started doing our research today. Much of the material we relied on for that book, which actually called upon the government to do more to protect the country from bioterrorist attacks, is now classified.

Overclassification is a serious, underappreciated challenge to our democracy. White House menus at state dinners are virtually classified. So too were the reasons why citizens could be put on a “kill” list without judicial review. The Obama administration, like its predecessors, has had cases thrown out of court after claiming that certain information would compromise state secrets. And the administration has closed meetings that the public used to attend, for example, meetings about the safety of nuclear plants and environmental protection assessments. In 2004, 64 percent of Federal

Advisory Committee meetings were completely closed to the public, according to the Federation of American Scientists’ “Secrecy Project.”

Are we in danger of becoming a national surveillance state? With all that’s happened since 9/11, with all that I’ve discussed here, the question for all of us, including here in Los Alamos, where secrecy is essential, is this: Do we have the right balance between secrecy and civil liberties? Of course the line was destined to shift after our country was forced to declare a war on terrorism, and in a world that may be increasingly filled with nuclear and other WMD, the use of which could kill or injure thousands, if not hundreds of thousands, of our citizens. But even given these dangers, have we gotten that balance right?

Overclassification is a serious, underappreciated challenge to our democracy.

As some of you may know, I went to jail for 85 days in 2005 to protect the identity of a confidential source. But over the past three decades, nearly two dozen journalists have been jailed in the United States for refusing to testify or disclose other types of information, according to the Reporters Committee. Now my former colleague at *The New York Times*, James Rosen [now at Fox News], faces jail for refusing to testify in a criminal trial against a source.

Under the Obama administration, prosecutors have brought forth seven leak-related cases involving journalists—more than double the number brought forth under all previous presidents combined. The administration is also using the 1917 Espionage Act against people who may be whistleblowers—officials who leaked classified information to the press to expose programs that were corrupt, deeply flawed, or (in their view) illegal.

And our government has increasingly resorted to using journalists to identify and testify against those sources. The most egregious example was the recent subpoena for the office, home, and cell phone records of my colleague James Rosen. He wrote a story in 2009 saying that the CIA believed, based on sources inside North Korea, that Pyongyang would test another nuclear bomb if more sanctions were heaped upon it. I can’t talk about the details of this case; I can only tell you that Rosen deleted material from his story that might have enabled the North Koreans to identify the government’s source. But his emails and telephone conversations with Stephen Kim, a Lawrence Livermore National Laboratory employee on loan to the State Department, helped the government identify Kim as the likely source and indict him. Kim has denied the charges.

But in this case, the government went beyond trying to find and punish a leaker. It sought and secured a warrant from a judge for Rosen's telephone numbers on grounds that he had also allegedly conspired to violate the Espionage Act by "soliciting information" from a government official. The warrant accused him of "flattering a source," that is, doing what journalists do every day, and what a free society depends on us to do to ensure that government does not abuse the enormous power it has acquired, especially given its growing technological prowess. What the Department of Justice was doing, in effect, was criminalizing the act of reporting. Attorney General Eric Holder sought to make reporting a national security crime.

When you start down that road, you are treading on very dangerous ground.

As a candidate, Obama vowed to support shield law legislation. Then his administration proceeded to help gut the measure that Congress considered.

Fortunately, from my standpoint, the outcry was so great in the Rosen case—even though the reporter worked for Fox News, which the Obama administration has also tried to delegitimize by saying it is not a news network but an arm of the Republican Party—that Attorney General Holder was forced to back down and issue new guidelines governing leak inquiries. He has pledged to tighten the circumstances in which a reporter's records can be obtained. President Obama, too, said he was "troubled" by this case and has vowed to support a federal shield law that would protect journalists from

having to testify before grand juries if it means compromising their sources in all but the most serious national security leaks. I would have been more impressed by the administration's response if Holder hadn't told Congress that he would never dream of using the Espionage Act against a journalist—until it was disclosed that he had personally signed off on the warrant against Rosen.

As a candidate, Obama vowed to support shield law legislation. Then his administration proceeded to help gut the measure that Congress considered. The shield proposals had become more or less toothless when they were finally doomed by Julian Assange's publication of hundreds of thousands of diplomatic cables and secret military planning documents through Wikileaks.

What we've increasingly seen since 9/11 is a pattern of government leaks of secret information when it suits an administration's interests.

Let's be honest. All governments, Republican and Democratic, decry the harm journalists cause by revealing secrets, choosing to blame the messenger for the message. And all governments provide their own leaks when it serves their interests to do so. Leaking is as American as apple pie.

But as Mark Feldstein, director of the journalism program at George Washington University, and many other First Amendment advocates have argued, on balance, far more damage to national security has been caused over the years by government secrecy and deceit than by the press's reporting of secret information. The classic example occurred under John F. Kennedy. At President Kennedy's request, *The New York Times* declined to publish information it had gotten about plans for the Bay of Pigs invasion—and later, after the fiasco unfolded, JFK asserted that it would have been better for the country if the newspaper had disclosed them.

What we've increasingly seen since 9/11 is a pattern of government leaks of secret information when it suits an administration's interests. Consider the leaking of classified sources and methods information about the killing of Osama



bin Laden—which resulted, apparently, in the arrest of a Pakistani doctor who worked with the Americans in locating bin Laden. Consider, too, “unofficial” or “unsanctioned” leaks of national security information in response to both government abuses and the overclassification of information that the public often has a right, and indeed a need, to know. It has been a rule of thumb in American politics: whistleblowers turn to the press to get the truth out when it is being suppressed. And rather than being a threat to American democracy, Feldstein and others argue (and I concur), it is a healthy and self-correcting mechanism.

Especially in times of war and terrorism, the tension between the twin goals of protecting national security, on one hand, while defending civil liberties—and in particular the freedom and independence of the press—on the other hand, is bound to intensify. And so it has. I’m not arguing that some leaks don’t damage national security. I disagree with many of my colleagues who have defended Private Manning, for instance, whose egregious dump of some 750,000 diplomatic cables and secret plans and correspondence has caused enormous diplomatic and personal damage to people who have cooperated with the United States while expecting confidentiality. I also think the publication of details of the Stuxnet computer virus may have hurt American interests. It has been publicly reported that three Iranian technicians were jailed as a result of those leaks. I have not been able to independently verify this.

No democracy can survive for long without a free, independent, and occasionally irritating and even irresponsible press.

So I’m not arguing against secrecy per se—especially when it involves nuclear weapons and other WMD expertise and technological developments and operations.

But there is a difference between prosecuting Private Manning and going after Thomas Drake, who sought to expose what many at the National Security Agency considered a wasteful, ineffective program that his agency had embraced. And there is surely a difference between

punishing Private Manning for violating her oath to keep the government’s secrets and, in addition, accusing Julian Assange of Wikileaks with violating the Espionage Act for having published them.

In a democracy there will occasionally be leaks that harm national security. But no democracy can survive for long without a free, independent, and occasionally irritating and even irresponsible press. If anything, given technological advances in the government’s and the private sector’s ability to monitor telephone and electronic communications, the government’s reluctance to curtail the official knee-jerk impulse to classify everything it does, in the name of national security, threatens not only our individual and collective rights, but the very national security the government ostensibly seeks to protect.

It also threatens legitimate secrets like those being kept here at Los Alamos. For if Americans come to distrust the government, how is our national security served? If they are repeatedly told that everything is secret, eventually they will come to suspect the need for even genuine secrets, including those that keep us safe. True national security secrets are jeopardized by the passion for secrecy.

No one has all the answers to these difficult challenges and issues confronting us. But so far, thanks in part to examples like Edward Snowden and Julian Assange, no matter what you think of them, a serious public debate about these issues has finally begun. ✦

~Judith Miller



The Academies Come to Los Alamos for a Summer of Science

Trent Jones, a junior at West Point, came to Los Alamos National Laboratory to explore the practical applications of his major, physics.

"I wanted to see how, exactly, physics is used in the world today," Jones said.

He spent four weeks working with a Laboratory mentor in the Materials Science and Technology Division, where most of his time was spent doing what he, as a physicist, says he loves to do: "work on a small scale." Alongside Laboratory technical staff members, he helped characterize materials, determining their internal structure and properties.

With plenty of hands-on work to be done, Los Alamos was the perfect place for Jones and 25 other students from U.S. military academies to spend part of their summer.

The materials Jones worked with were destined for use in experiments at the Laboratory's Dual-Axis Radiographic Hydrodynamic Test (DARHT) facility. DARHT's "dual axis" consists of two linear accelerators, set at right angles to each other, that focus electron beams on a single thin metal target. At the target the beams' energy is converted into x-rays that are used to image the mock-up (no plutonium) of a nuclear weapon primary as it implodes during experiments (see p. 41 in "Then & Now").

Jones, along with some of his team members, was also given some housekeeping work. He helped remove impurities from tantalum foils before they were used as DARHT targets. The foils were placed in an acid bath that was then exposed to ultrasonic waves.

"My high school chemistry teacher would be jealous. I got to work with nitric and hydrofluoric acid in really high concentrations," Jones said.

With plenty of hands-on work to be done, Los Alamos National Laboratory was the perfect place for Jones and 25 other students from U.S. military academies to spend part of their 2013 summer. Los Alamos hosted the 26 cadets

and midshipmen through the Service Academies Research Associates (SARA) program. Los Alamos' annual summer SARA program brings students from the U.S. military academies to Los Alamos, where they get practical academic experience by working at the Laboratory for four to six weeks. The National Nuclear Security Administration's Military Academic Collaboration program provides the funding to support the SARA program, which is designed to reinforce classroom experiences with real-world scientific projects that support the Lab's national security mission.

"The purpose of the SARA program is to help create more scientifically aware military decision makers who understand and appreciate the science and technology capabilities of the Lab," says Jon Ventura, who leads the Laboratory's SARA program.

We put them to work on problems that have a direct bearing on each student's academic program—and on the work of the Laboratory.

When students come to the Laboratory, they leave an academic environment of "practice problems" and enter a lab environment where they can take on unsolved problems that impact the world of science.

"We put them to work on problems that have a direct bearing on each student's academic program—and on the work of the Laboratory," says Ventura.

Students have the opportunity to work one-on-one with mentors and other LANL staff members on a large variety of projects in a lab environment that allows them to learn and contribute. Mentors volunteer to teach students about their specific area of expertise and introduce students to new scientific and technical topics.

Several of the 2013 participants worked with co-mentors Tim Goorley and Avneet Sood, group leaders in the Laboratory's Computational Physics Division. Goorley says his students used Monte Carlo computer codes to model the interaction of radiation with different materials. Students simulated how neutrons traveled through and interacted with a cylinder of highly enriched uranium, creating gamma rays that were then picked up by a sensor. They then compared the results of their simulation with experimental data to see how accurate the simulation was.

Todd McLaughlin, a junior at West Point, worked with the life-extension program (LEP) for the B61, a LANL-designed thermonuclear bomb. The B61, like all weapons in the stockpile, is getting progressively older, and Los Alamos is responsible for keeping the bomb safe, secure, and reliable.

A midshipman from Annapolis, Nicholas Butler, worked on the Superconducting Quantum Interference Device (SQUID) team. SQUIDs are small devices (typically a millimeter in size and connected to centimeter-size "pick up" coils); they measure ultralow magnetic fields.

SQUIDs can do many jobs. For example, they can detect metal particles even 10,000 times smaller than the diameter of a human hair—nanoparticle size—and that means SQUIDs can be used to detect cancer cells. They can do that through the use of ultralow magnetized nanoparticles of iron oxide.

The iron oxide particles are nontoxic. They can be attached to cancer-specific antibodies and together with them, be injected into a patient's body. The antibodies with their hitchhiking magnetized nanoparticles bind to receptors on the cancer cells. A SQUID-based MRI (magnetic resonance imaging) device can then detect and image the iron oxide nanoparticles, revealing the location of the cancer cells for diagnosis and targeted treatment.

SQUID technology may also be used in a new class of MRI machine. The SQUID team is using this technology to develop an easily portable, lightweight MRI device. Butler said this project was especially exciting because the small SQUID-based MRIs will be suitable for use in places without access to large, conventional MRI machines, such as combat support hospitals.

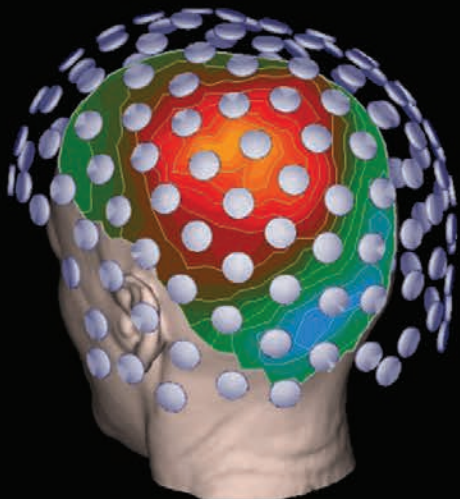
There is a wide variety of projects at Los Alamos for students like Jones, McLaughlin, and Butler. LANL offers students learning experiences across a vast set of scientific disciplines, with staff members eager to share their knowledge and expertise. Students and staff collaborate on projects, and Goorley says communicating with students is as valuable for the scientists as it is for the students. It gives students an opportunity to learn from the experts, and it allows staff members to practice sharing complex ideas in a way that others can understand.

Christopher Wink, a West Point cadet assigned to the Neutron Science and Technology group, said his team did a great job of making sure he fully understood what he was working on and why it was relevant.

"Everyone I worked with did a really good job of bringing me up to speed even though I don't have, like, three PhDs," Wink joked.

The environment at the Laboratory allows ideas to flow.

SARA students also provide a fresh look at problems facing LANL, and they may come up with new ideas. West Point's Steven Sloan, for example, reviewed the way the Los Alamos Plutonium Facility processes plutonium-238 (Pu-238). Los Alamos purifies Pu-238 and compresses the material



Battlefield SQUIDs

Current magnetic resonance imaging (MRI) scanners use a powerful magnetic field to generate images of soft body tissue.

Although they produce detailed images, they have a few drawbacks. They use very large, heavy, strong magnets that can cause metal in a patient's body to move or get hot and expand, causing trauma. Today, many people have medically necessary metal implants such as pacemakers, and combat wounds often contain metal shards and bullet fragments. Also, MRI machines are typically large, not portable, and expensive (over \$1 million).

SQUID-based ultralow-field MRIs, on the other hand, do not require a strong magnetic field—the field is 30 to 30,000 times smaller—so SQUID-based MRI scanners are safe for patients with metal in their bodies. SQUIDs allow the scanners to be compact, portable, and inexpensive.

The SQUID team at Los Alamos is working to create an MRI scanner that can be taken where it is needed, that is, to poorer countries and to the battlefield to support our troops.



Air Force cadet Steven Owens works at his computer for the Space Science and Applications group. He worked on a project called "Wide Field-of-View Plasma Spectrometer," which is developing a new type of instrument to measure plasmas (gases of charged particles) in space. (Photo: Los Alamos)

into pellets that can be used in radioisotope thermoelectric generators, "batteries" that have provided power for several NASA space missions. Sloan was able to suggest ways that Los Alamos could process these pellets in a more efficient, cost-effective way. McLaughlin said he was able to contribute a new idea to help the LEP for the B61.

"The environment at the Laboratory really allows ideas to flow, and it's easy to work with everybody. Anybody can contribute at Los Alamos," McLaughlin said. "One of the biggest things I've learned here is that students should not discount themselves from having brilliant ideas."

Mentoring is a great way to bring in new perspectives, but it is also an extra duty for LANL staff members, who voluntarily teach SARA students, often for personal reasons. Both Goorley and Patrice Stevens, who works in the Plutonium Facility, say they got involved with mentoring students because the military is in their blood. Stevens and Goorley come from military families and see the SARA program as a way to give back.

You cannot be successful doing high-level science without a mentor.

Stevens had a mentor when she first came to the Lab, and she says her experience is another reason she mentors SARA students today. Her mentor was a huge part of her life inside and outside of the Lab and, she says, showed her the ropes and led her through the world of science. According to her, no one can be successful doing high-level science without a mentor who both teaches and takes care of the mentee. She believes the mentoring relationship with SARA students is about getting them involved with problem solving and showing them the wide range of possibilities at the Lab.

To supplement their in-depth learning with mentors and other LANL staff members, students explore the variety of work at the Laboratory. Students are given tours of Lab property and lectures on a variety of subjects.

During the summer of 2013, students toured the Strategic Computing Complex (SCC), which houses the supercomputing system at Los Alamos. The SCC also has “the cave,” a viewing room that allows researchers to walk around 3D visualizations of their computer simulations and even interact with them. They also went to Technical Area 55, home of the Plutonium Facility.

Some students were taken to the Nevada National Security Site, where they performed experiments in the Device Assembly Facility. They spent time touring and visiting craters created by underground nuclear tests (which ended in 1992) and the U1a underground test facility, where subcritical (no nuclear yield) tests are conducted. In addition to visiting these important locations, students learned about

a wide range of science and technology from experts. They were able to attend lectures on a variety of subjects, such as the development of an HIV vaccine and Los Alamos’ involvement with ChemCam, a laser on the Mars mission’s Curiosity rover. The laser vaporizes small rock or soil samples so their elemental composition can be determined.

The students were able to meet Laboratory Director Charlie McMillan and Admirals Richard Mies (retired) and William McRaven, commander of the U.S. Special Operations Command.

“In the military, the director of the Laboratory would be considered a four-star general,” says Butler, “but here you call him by his first name. That’s cool.”

LANL also strives to give students an opportunity to learn about New Mexico. Students are encouraged to explore Los Alamos and the surrounding areas, which is something they can do both individually, in groups, and with their mentors. Michael Fitzgibbon, a midshipman from Annapolis,



West Point cadet Christopher Wink, along with his LANL mentor David Holtkamp and LANL staff member Jeremy Payton, stand at the Sedan Crater at the Nevada National Security Site. The Sedan Crater, the largest man-made crater in the United States, is the result of the July 6, 1962, Sedan nuclear test. The crater is over 300 feet deep and 1,280 feet in diameter. (Photo: Los Alamos)



Steven Sloan, a West Point cadet, looks into a glovebox in the Plutonium Facility. Missions within the facility include plutonium processing in support of stockpile stewardship, manufacture of plutonium energy sources for space missions, and materials disposition in support of nuclear nonproliferation, nuclear counterterrorism, and nuclear energy. (Photo: Los Alamos)

said he went running with his mentor in the Jemez Mountains, just west of Los Alamos. Groups of students also climbed Wheeler Peak, the tallest mountain in New Mexico; rafted down the Rio Grande; and went off-roading and hiking in the mountains.

Other students, including Wink and Sloan, explored New Mexico's rich Native American history and culture by visiting archeological sites like Bandelier National Monument and Taos Pueblo, a Native American community that is over 1,000 years old.

In the military, the director of the Laboratory would be considered a four-star general, but here you call him by his first name. That's cool.

SARA students are encouraged to experience and enjoy LANL and the surrounding area because the Lab wants students to look at their time in Los Alamos as more than just

an educational experience. Working at the Lab is a great way for students to experience the many adventures in and out of Los Alamos and to create connections that will last a lifetime. They work with mentors that care about students as individuals. Goorley says mentoring is about building connections with both the military and the students themselves. Stevens also believes that mentoring SARA students is about more than just sharing scientific expertise. "I think it's very important to bring students into your family," says Stevens. "I want to show students not only how scientists work, but also how they live."

Students said they enjoyed spending time with their mentors, and they also felt LANL was an unparalleled learning opportunity.

"It's such an enlightening experience to be around this sort of brain power in this sort of environment," says McLaughlin. "You can ask whatever questions you want and learn more here in a week than maybe in six months anywhere else."

Sloan said the SARA program helped him understand the complexities and complications of nuclear stockpile stewardship and gave him the opportunity to connect with

lots of interesting people. Phillip Ellsworth, a midshipman from Annapolis who worked in the Shock and Detonation Physics group, said his education at the Lab would be helpful because he plans to work on submarines with weapons designed at LANL.

Many students also said their internship with LANL will help them make important career decisions. Jones said working at the Lab has helped him think about what he wants to do after

his military commitment and what he wants to spend his time working on.

“We hope that, based on their summer experience, they would consider working here,” says Ventura.

It seems Ventura’s hope is well founded. Students have already asked about coming back to the Lab for another summer. ✦

~Marissa Higdon



Annapolis midshipmen stand at the top of Wheeler Peak. Wheeler Peak summit is 13,167 feet, the highest point in New Mexico. (Photo: Los Alamos)



U.S. Air Force Colonel Kelvin Townsend was assigned to Los Alamos as an Air Force Nuclear Fellow to strengthen the partnership between the Air Force and the Laboratory. (Photo: Los Alamos)

What Is an Air Force Fellow?

Employees at Los Alamos National Laboratory might have wondered about the man in the olive green flight suit walking around the National Security Sciences Building. Who is he? What is he doing? Well, I am that man—U.S. Air Force Colonel Kelvin Townsend—and I was temporarily assigned to Los Alamos for 12 months as an Air Force Nuclear Fellow. I was one of 114 participants in the Air Force Fellows program's 2012–2013 class.

The Air Force Fellows program is overseen by the Air Force Research Institute at Maxwell Air Force Base, Alabama. The Air Force provides competitively selected Air Force officers and Air Force civilian employees with an in-depth education in national security policy. Participants spend 12 to 18 months in residence at a distinguished civilian institute, the Department of Defense, or another key government agency or department. Institutions are selected because of their prominence in security affairs and their ability to provide Fellows with a spectrum of viewpoints.

The program plays a major role in contributing ideas for enhancing national security and ensuring the continuing effectiveness of the United States Air Force. It does that through three main goals. The first goal is strategic communication—solidifying the relationship between the Air Force and the civilian academic and policy communities, as well as providing the Fellow with opportunities to deliver current Air Force strategic messages to civilian and government counterparts. Second, the program broadens and

develops senior leader competencies. Finally, Fellows evaluate national and international security policy and processes by analyzing current perspectives on defense policy and strategy issues and by reviewing technologies critical to the strategic warfare capabilities of the United States and its allies.

The specific focus of my fellowship at Los Alamos was doing research on the nuclear enterprise and looking for efficiencies and areas of improvement. I was provided with opportunities to witness activities at the three weapons laboratories and the Nevada National Security Site. I also visited Oak Ridge National Laboratory in Tennessee.

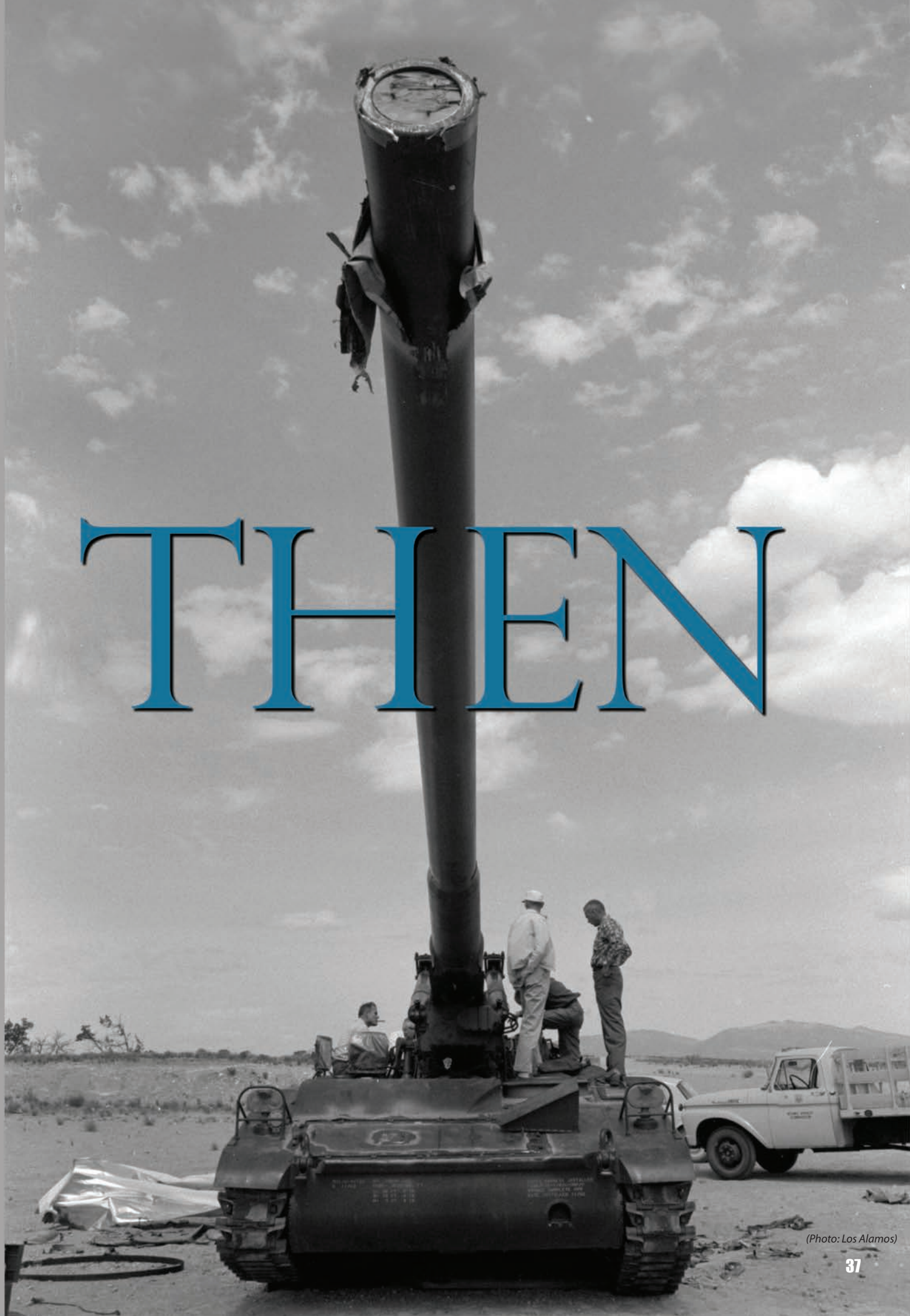
My time at Los Alamos was spent within the Weapons Program, where I served as a liaison between the Air Force and both the B61 and the W78 life-extension programs. Being in the Weapons Program provided me opportunities to interact with the weapons engineers, explosive experts, and physicists. I was able to brief Laboratory staff members on the duties of Air Force personnel and took part in many Laboratory-sponsored briefings. In addition, I hosted many visits of Air Force and other Department of Defense personnel to the Laboratory, as well as visits of LANL scientists and engineers to Air Force bases. Such visits proved invaluable for both Los Alamos and the Air Force because they gave Los Alamos staff firsthand knowledge of exactly how Los Alamos-designed weapons systems are deployed, operated, and maintained by the Air Force at these sites. Any challenges to these processes could be seen up close and possible solutions discussed, right there with the Air Force staff that would be implementing the improvements.

My fellowship confirmed my belief that a strong nuclear deterrent is achieved through resource and infrastructure investment, increased advocacy, continued nuclear competence, human capital development, and organizational reform. Resource investment is the money put into maintaining and operating the weapon systems. Infrastructure investment involves updating or replacing old and outdated support equipment and facilities. Advocacy involves stating the case for and supporting programs within the nuclear enterprise. These activities must occur within both the Department of Defense and the Department of Energy.

My time here has provided valuable insight into the role of the Department of Energy and its weapons labs in the nuclear enterprise. My next assignment is in Washington, D.C., where I will serve as chief of Nuclear Capabilities at Air Force Headquarters. The personal connections I made at Los Alamos and the lessons I learned while here will serve me well in my new position. ✦

~U. S. Air Force Colonel Kelvin Townsend

THEN



(Photo: Los Alamos)



(Photo: Los Alamos)



(Photo: Los Alamos)



(Photo: Los Alamos)

Since its inception in 1943, the Laboratory has done experiments to understand shock and detonation physics and the reactions of nuclear weapon materials to shock waves and other extreme impacts.

These black-and-white photographs, taken at a Laboratory testing site 50 years ago (on the Lab's 20-year anniversary in 1963) show a variety of cannons used for these experiments. The cannons would fire experimental projectiles of various types and materials into targets positioned in front of berms (large "catcher boxes") filled with, for example, soil, wood chips, and vermiculite. The berms captured the projectiles and targets, which could then be retrieved and studied.

NOW

*Photographs celebrating the
Laboratory's past and present*

Firing cannons outdoors ended in 1972, but the Lab is still doing this same kind of research on nuclear weapon materials.

Today the Lab uses “gas guns” situated inside specially designed laboratories. Gas guns, like the one shown below, use a non-gunpowder-based, high-pressure gas to fire modern projectiles into modern catcher boxes that, like decades ago, permit the projectiles and targets to be retrieved and studied.



(Photos: Los Alamos)



(Photo: Los Alamos)



(Photo: Los Alamos)



(Photo: Los Alamos)

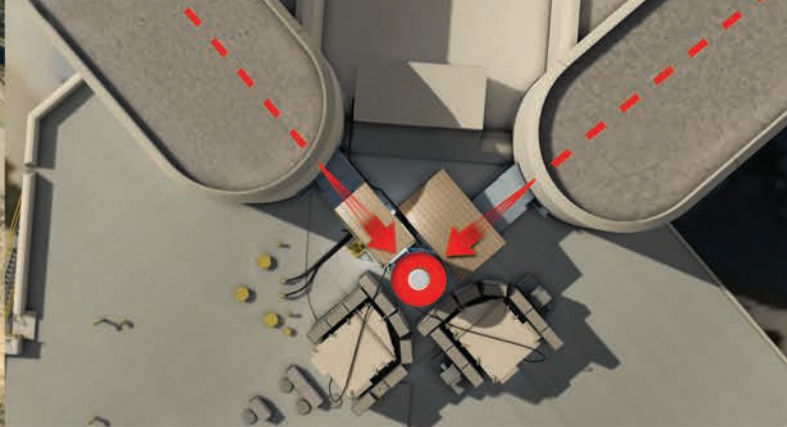
THEN



Experiments using high explosives produced brilliant fireballs in front of the metal bunker that was home to PHERMEX (Pulsed High-Energy Radiographic Machine Emitting X-Rays), the nation's premier radiographic test facility during the Cold War. PHERMEX generated bursts of x-rays needed to take a series ("movie") of high-speed pictures (radiographs) of implosion experiments that mimicked the implosion of a nuclear weapon's nuclear-fuel core. The radiographs recorded what was happening.

In a real nuclear weapon, high explosives produce the pressures needed for an implosion to force the fuel into its supercritical phase—uncontrolled fission—resulting in a nuclear explosion. However, before reaching supercriticality, the core materials actually melt and flow like fluids; consequently, experiments that mimic this implosion process are called hydrodynamic tests, or hydrotests. Radiographs of the fluid's behaviors are critical to understanding weapon performance.

Los Alamos National Laboratory



NOW

After more than 40 years and 1,000 hydrotests, in 1999 PHERMEX was replaced by the Dual-Axis Radiographic Hydrodynamic Test facility (DARHT), one of the world's most powerful x-ray machines. At DARHT two x-ray beams, aimed at right angles to each other, create radiographs for 3D images of implosions. One of DARHT's beams produces four sequential high-resolution radiographs that form, in effect, a short "movie" of the implosion. Each implosion at DARHT takes place safely inside a giant containment vessel like the one shown below.



(Photo: Los Alamos)


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The Nuclear Materials Safeguards and Security Upgrade Project at the Lab's Plutonium Facility, shown here, is officially finished. It is a never-before-tried integration of the most advanced physical security technologies available. "The security of our nation's nuclear material is our most important responsibility," says Michael Lempke, the National Nuclear Security Administration's acting chief of Defense Nuclear Security. (Photo: Los Alamos)



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